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GB 1040313 A GB 0461875 A

(58) Field of Search
UK CL (Edition P) B1B BGA BGC BGD BKE
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(54) Abstract Title
Desalination of water

(57) A process for the desalination of salt-containing water (16), comprises feeding a web (26) of water-absorbent material through a body (12) of brackish water (16) into an air space (28) above said body (12) of water. A stream of air (52) is directed over said web (26) in said air space (28) to evaporate water therefrom. Thereafter said web (26) is returned to said body (12) of water. The water-containing air stream (52) is directed to a condensation space (42) where desalinated water is condensed therefrom.

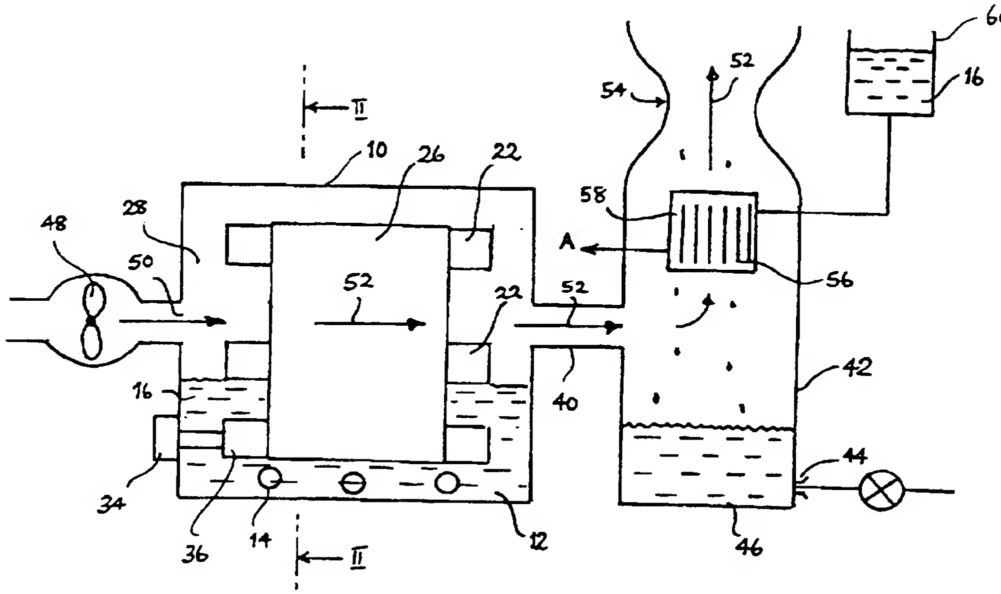

FIGURE 1

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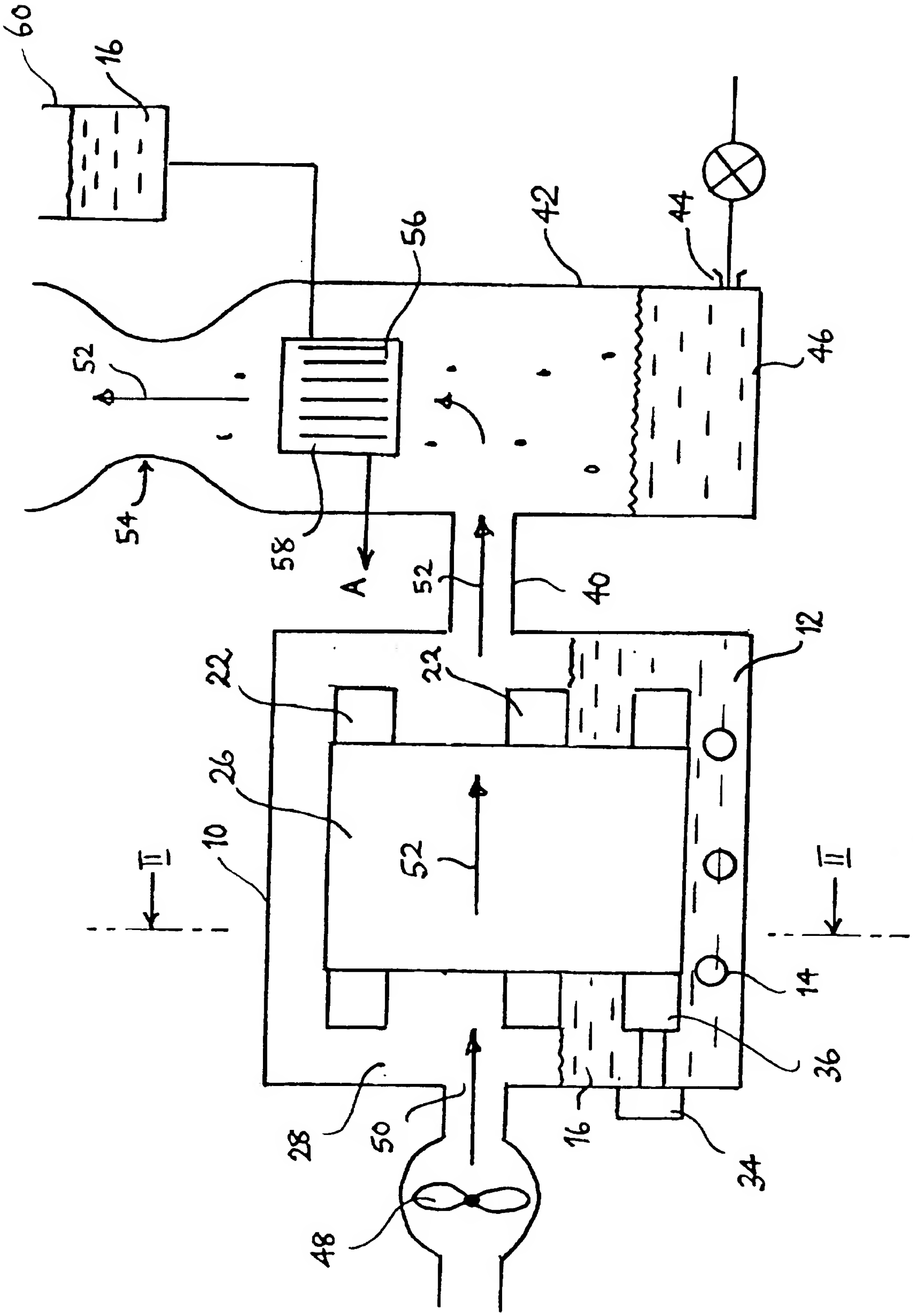
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FIGURE 1

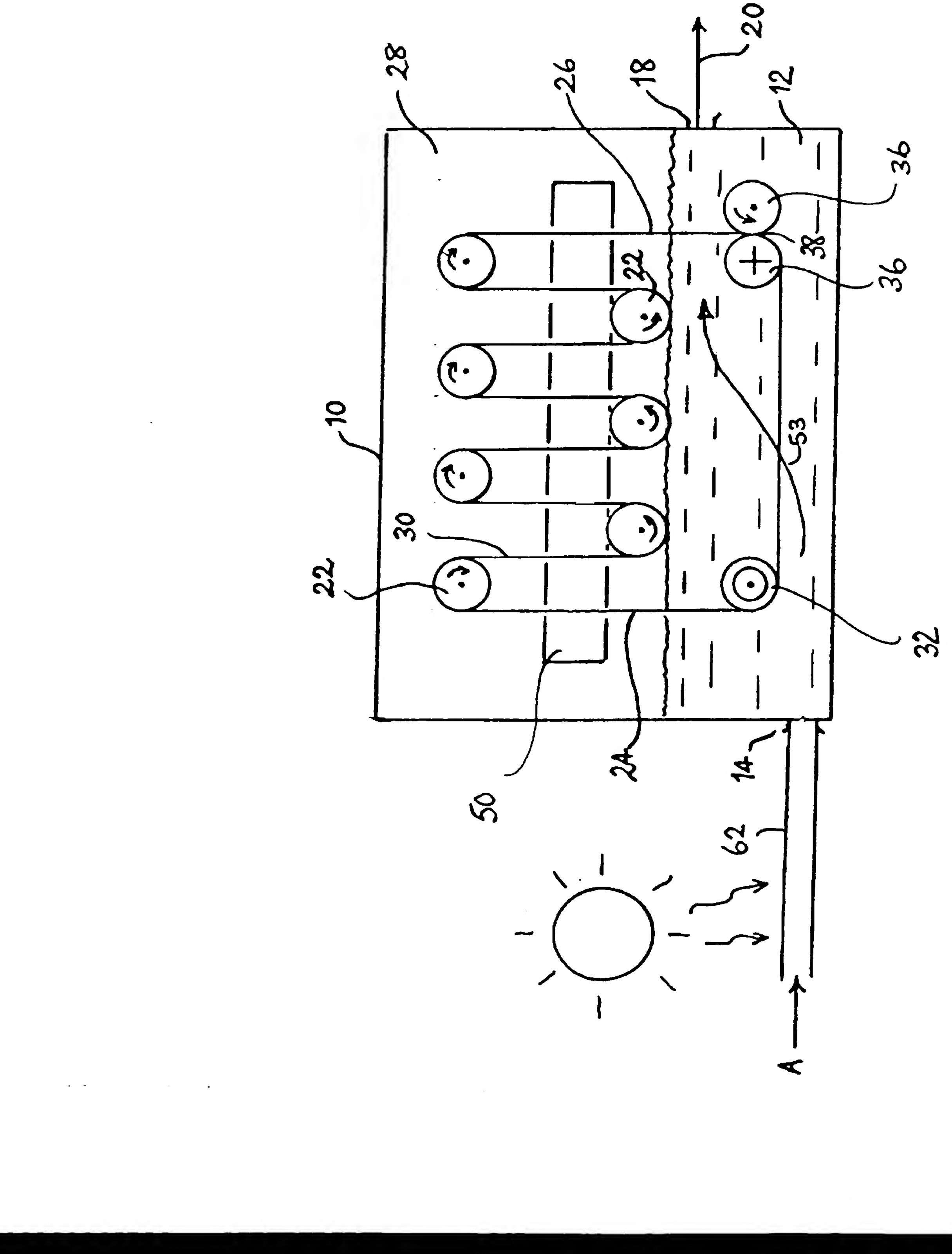

FIGURE 2

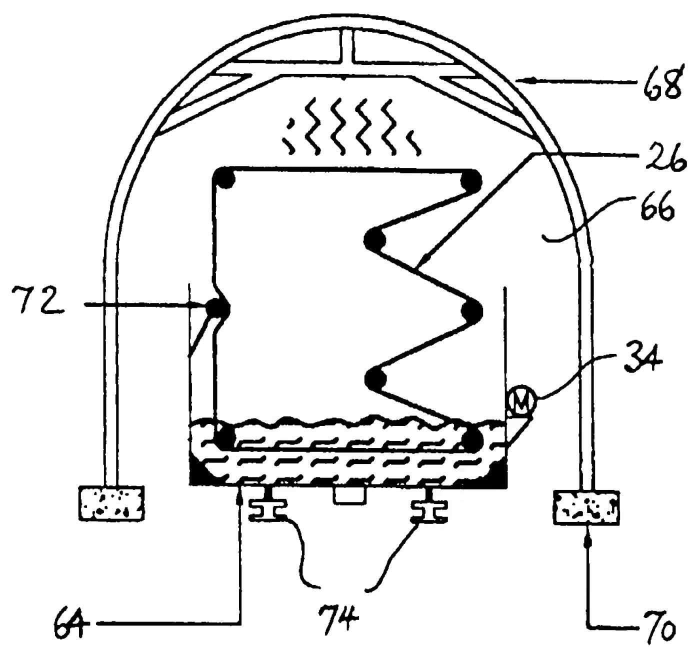

FIGURE 3

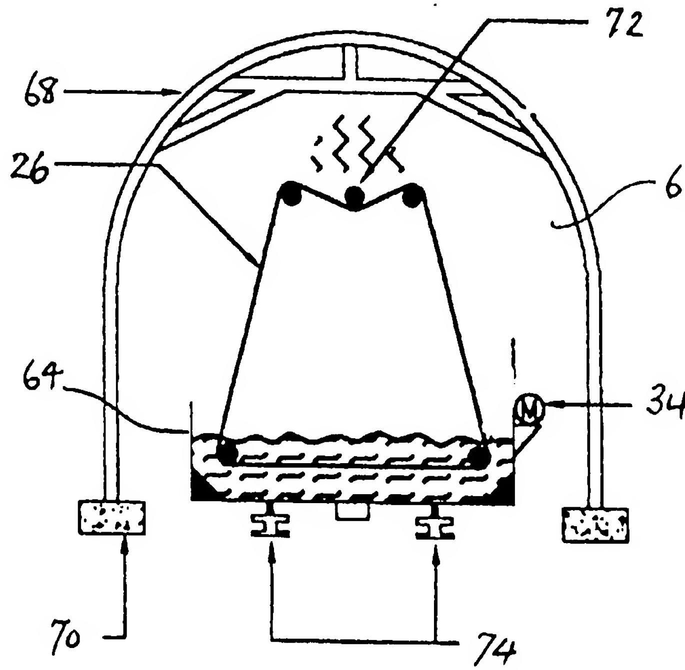

FIGURE 4

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DESALINATION OF WATER

Field of the invention

This invention relates to a process for the desalination of salt-containing water, especially sea water, and to an apparatus for carrying out such a process.

Background of the invention

There is an increasing world-wide need for fresh water, especially for human consumption, but also for agricultural and industrial needs. Although much of the planet is covered with water, it is in an unsuitable form. Sea water contains typically nearly 3% by weight of sodium chloride, together with up to 1% of other salts including magnesium chloride, calcium sulphate, potassium chloride and sodium bromide. Water containing more than 1000 ppm salt is considered unfit for human consumption. Not only is sea water therefore unsuitable but so are many other sources of water, referred to generally as brackish water.

The art of desalinating water to make it fit for human consumption is well established. A number of techniques are known including evaporation, membrane separation, electrolysis and ion-exchange processes, evaporation being the most common. Evaporation requires raising the temperature of the brackish water to close to or above boiling point to generate steam which is then condensed to yield the desalinated water. While this process may be convenient in locations where plentiful sources of heat

energy are available, such as on board ship, in many locations heat energy is not so readily available. Such processes are not especially energy efficient, since most of the energy taken up in raising the temperature of the water is lost again when the water vapour condenses. Furthermore, where evaporation occurs at or close to the boiling point, the violence of the process may result in the carry-over into the condenser of a salt-containing mist.

There is therefore a need to provide a process for the desalination of brackish water with more efficient use of energy.

SUMMARY OF THE INVENTION

We have discovered that this objective, and other useful advantages, can be achieved by evaporating water from a web of water-absorbent material which has passed through a body of the brackish water into an air space above the body of water.

Thus, according to the invention, there is provided a process for the desalination of salt-containing water, comprising feeding a web of water-absorbent material through a body of brackish water into an air space above the body of water, directing a stream of air over the web in the air space to evaporate water therefrom and thereafter returning the web to the body of water, and directing the water-containing air stream to a condensation space where water is condensed therefrom.

The body of water and the air space above are conveniently defined by an evaporator having at least an inlet for the brackish water, an air inlet and a gas connection between the air space and a condensation chamber. The evaporator may be a generally closed structure, incorporating inlets and outlets for the brackish water and the air stream. Alternatively, the evaporator may be constituted by one or more removable open top tanks located within an enclosing structure, for example having a tunnel-like configuration.

As water is evaporated from the web in the air space, the liquid carried by the web becomes salt-enriched and in an extreme case salt crystallises on the web. This crystallisation does not however generally occur until the salt concentration in the liquid exceeds about 25%. The salt-enriched liquid and/or the crystallised salt is preferably removed from the web by dispersal in the body of water. That is, as the web returns to the body of water, the salt-enriched liquid disperses in the body of water, to be replaced by further brackish water. Eventually, in a closed system, the salt concentration in the body of water would rise to the point that crystallisation in the body of water starts to occur. This is preferably avoided, so as to avoid the need to provide mechanisms for the removal of such crystallised salt. We therefore prefer to pass brackish water continuously into the body of water and to continuously remove salt-enriched liquid therefrom, thereby to establish a flow of liquid through the body of water. This results in the disposal of the salt-enriched liquid, but where the source of brackish water is substantial, the

volume used per unit volume of generated desalinated water is not particularly significant in the cost and energy consumption equations. While the requirement that the water should flow through the evaporator would normally mean the use of one or more pumps, a simple construction can be envisaged where the source of brackish water is at a higher level than the discharge of salt-enriched liquid. The liquid flow through the evaporator may then be achieved by relying on gravity.

To encourage the dispersal the salt-enriched liquid and/or crystallised salt from the returning web, we prefer that the body of water is agitated. In one embodiment, this is achieved by ultrasonic vibration. In an alternative or additional embodiment, the body of water is agitated by the flow of further brackish water into the bath and the flow of salt-enriched liquid out of the bath.

The path along which the web is fed through the body of water and through the air space, preferably comprises a meandering portion, at least in the air space above the body of water. In this manner it is ensured that the surface area of the web in the air space is maximised, thereby maximising the evaporation of water therefrom. Ideally, the web path length through the air space is greater than that through the body of water.

In one embodiment, the web is continuous and passes over a number of guide rollers which together define the meandering path. The optimum number of guide rollers used, and hence

the number of alternating web runs in the meandering portion, will depend *inter alia* upon the ambient temperature. One or more of these rollers is coupled to a drive motor. One or more of these rollers may be so arranged to provide a tensioning effect on the web. The surface of each these rollers is preferably formed of a material which will be inert to the salt-containing water, such as chemically resistant alloys and elastomeric materials. To ensure proper alignment of the web during operation of the apparatus, the web may be provide with sprocket holes or attached rings to engage in cogs carried on one or more of the guide rollers.

The flow of air through the air space is preferably arranged to be generally in a direction across the surface of the web, rather than through the web. This is more efficient in terms of the energy required per unit of water evaporated. The flow of air will generally be achieved by the use of one or more fans. Energy for driving the fans may be derived from solar panels. A simple alternative construction can be envisaged where the evaporator is so positioned relative to the prevailing wind direction, that such fans can be dispensed with.

Although the process can be carried out at ambient temperatures, it is of advantage to pre-heat the brackish water above ambient temperature. This pre-heating can be achieved in a simple manner, in locations where there is plentiful solar radiation, by passing the brackish water through a pipe formed of a "green-house" material

(transparent to solar radiation but not to lower energy heat radiation), such as glass or certain plastics materials such as polyethylene.

The web may be heated as it enters the air space. Where the web path is defined by a number of rollers, one or more of these rollers may be heated. Ideally it is the first roller in the air space or the last roller in the body of liquid which is heated.

In an alternative embodiment, the web is in the form of a disk supported on a rigid (e.g. stainless steel) ring, rotational about an axis which lies closely above and is substantially parallel to the surface of the liquid in the evaporator. A portion of the disk lies below the surface of the liquid. As the disk rotates, liquid picked up by those portions of the web under the surface of the liquid are transported into the air space above the liquid. A counter-current air flow is provided across the face of the disk to evaporate water therefrom. As the disk continues to rotate, portions of the web now carrying salt-enriched liquid or crystallised salt now return to the body of the liquid. A battery of such disks could be provided, with a mutually parallel orientation, all being rotated about a common axis. The disk axis may be defined by a hollow shaft, through which hot water is passed to increase the rate of evaporation from the web disk. This embodiment has the advantage that no bearings and sealing devices need to be provided below the level of the liquid and that energy wastage is minimised.

The condensation space preferably includes a portion of restricted cross-section through which the water-containing air stream is directed. For example, the condensation space may have a "cooling tower" construction, where the water containing air is passed upwardly through a column of decreasing cross-section, before the cross-section enlarges again towards the upper outlet of the column. This "venturi" construction causes condensation of the water from the water-containing air. The condensed water falls as "rain" to the bottom of the column from where it may be collected. The cooling tower may be a solid construction or formed of flexible sheet material supported by a light frame. The latter construction may enable the apparatus to be more portable.

The condensation space may additionally or alternatively include a cooled condensation surface, against which the water-containing air stream is directed. The condensation surface is cooled, for example, by the brackish water, before the latter is passed to the body of water in the evaporator. This is especially convenient where the source of brackish water, for example seawater, is at a temperature below the ambient air temperature, as will often be the case.

A suitable apparatus for carrying out the method according to the invention comprises an evaporator in which the body of liquid can be located, with an air space above the surface thereof, guide means defining a web path through the body of liquid and the air space, drive means for driving

the web of absorbent material along the web path, a condensation chamber in gas connection with the air space in the evaporator and means for providing a flow of air through the air space over the surface of the web and to the condensation chamber.

In a preferred embodiment, the evaporator has an inlet for brackish water, an outlet for salt-enriched liquid, guide rollers defining a meandering path for the web through the air space, a pump for pumping air across the surface of the web, a pipe connecting the air space to the condensation chamber. The condensation chamber is in the form of a cooling tower with the pipe from the evaporator entering towards the bottom thereof, but above an outlet for the desalinated water.

The water-absorbent material of which the web is composed may be natural or synthetic, but is preferable a hydrophilic material. Calico cotton is a suitable example. The weave of the material should be close enough to encourage good wicking and retention of water by the web, but not so close that salt-enriched liquid and crystallised salt cannot easily be dispersed when the web returns to the body of water.

The invention will now be further described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatical representation of an apparatus

for carrying out the present invention;

Figure 2 is a cross-section of the evaporator, taken on the line II - II in Figure 1; and

Figures 3 and 4 show modifications of the evaporator of the embodiment shown in Figures 1 and 2.

Referring to Figures 1 and 2, the apparatus comprises an evaporator 10 in which a body 12 of sea water is located. The evaporator 10 has an inlet 14 for pre-heated sea water 16 to be desalinated and an outlet 18 for salt-enriched liquid 20.

Guide rollers 22 define a web path 24 for a web 26 of calico cotton through the body 12 of liquid and through the air space 28 above the surface thereof, the web path 24 comprising the meandering portion 30 in the air space 28. The web 26 passes over a heated roller 32 which heats the web 26 as it enters the air space 28. A drive motor 34 is coupled to a drive roller pair 36 which define a nip 38 therebetween, through which the web path 24 passes. Operation of the drive motor 34 drives the web 26 along the web path 24.

A pipe 40 connects the air space 28 in the evaporator 10 to a cooling tower 42, with the pipe 40 from the evaporator 10 entering towards the bottom thereof, above an outlet 44 for the desalinated water 46.

A fan 48 provides a stream 52 of air from air inlet 50 through the air space 28 over the surface of the moving web 26 to evaporate water therefrom. Thereafter the web 26 returns to the body 12 of sea water. Salt-enriched liquid carried on the web 26 after evaporation is removed therefrom by dispersal in the body 12 of sea water. The body 12 of sea water is agitated by the flow of further sea water 16 into the bath and the flow of salt-enriched liquid 20 out of the bath, as indicated by the arrow 53.

The air stream 52, now loaded with water vapour evaporated from the sea water carried on the moving web 26, continues along the pipe 40 and to the cooling tower 42 where water is condensed therefrom.

The cooling tower 42 includes a portion 54 of restricted cross-section through which the water-containing air stream 52 is directed. The cooling tower 42 also incudes a cooled condensation surface 56 of a heat exchanger 58, against which the water-containing air stream 52 is directed. The heat exchanger 58 is cooled by cold sea water 16, fed from a supply 60 thereof, before the sea water is passed to the evaporator 10. The sea water 16 is thereby pre-heated. To further pre-heat the sea water above ambient temperature before it enters the evaporator 10, after leaving the heat exchanger 58, (point A in Figures 1 and 2) it passes along a polyethylene pipe 62, exposed to solar radiation.

Figures 3 and 4 show a modification of the evaporator of the embodiment shown in Figures 1 and 2. In these embodiments,

the sea water is contained within an open top tank 64, positioned within a tunnel 66 formed of a green-house plastic material, such as polyethylene, supported on a frame 68. The tunnel 66 is supported on a brick or concrete foundation 70. The fan 48 of the embodiment shown in Figures 1 and 2 is dispensed with. Air enters the evaporator through air bricks arranged in the foundation and natural convection is relied upon to generate the necessary air flow within the evaporator, thereby saving on the electrical energy requirements of the apparatus. In the embodiments of Figures 3 and 4, one of the rollers over which the web passes, is a tensioning roller 72.

The tank 64 is mounted in the tunnel on rails 74, or rollers, enabling the tank to be easily removed from the tunnel 66, for servicing purposes.

Modifications of these embodiments are possible. For example, one end of the tunnel may be fully open to provide the air intake to the evaporator. A number of tanks may be positioned in the same tunnel, with the sea water being supplied either independently to each tank, or passing from one tank to another is cascade fashion. The cross-section of the tunnel may increase in the direction towards the cooling tower (or other condensation device) to provide an air space of increasing volume to accommodate the increasing level of water vapour in the air flow through the tunnel.

CLAIMS

1. A process for the desalination of salt-containing water (16), comprising feeding a web (26) of water-absorbent material through a body (12) of brackish water (16) into an air space (28) above said body (12) of water, directing a stream of air (52) over said web (26) in said air space (28) to evaporate water therefrom and thereafter returning said web (26) to said body (12) of water, and directing said water-containing air stream (52) to a condensation space (42) where water is condensed therefrom.

2. A process as claimed in claim 1, wherein salt-enriched liquid carried on said web (26) after evaporation and/or salt which crystallises on said web (26) during evaporation is removed therefrom by dispersal in said body (12) of water.

3. A process according to claim 2, wherein said body (12) of water is agitated to assist in the dispersal of said salt-enriched and/or crystallised salt from the returning web (26).

4. A process according to Claim 3, wherein said body (12) of water is agitated by ultrasonic vibration.

5. A process according to Claim 3, wherein said body (12) of water is agitated by the flow of further brackish water (16) into said body (12) of water and said flow of salt-enriched liquid (20) out of said body (12) of water.

6. A process according to Claim 1, wherein said web (26) is fed along a web path (24) through said body (12) of water and through said air space (28), said web path (24) comprising a meandering portion (30) in said air space (28).

7. A process according to Claim 1, wherein said brackish water (16) is pre-heated above ambient temperature.

8. A process according to any preceding claim, wherein said web (26) is heated as it enters said air space (28).

9. A process according to any preceding claim, wherein said condensation space (42) includes a portion (54) of restricted cross-section through which said water-containing air stream (52) is directed.

10. A process according to any preceding claim, wherein said condensation space (42) incudes a cooled condensation surface (56), against which said water-containing air stream (52) is directed.

11. A process according to claim 9, wherein said condensation surface (56) is cooled by said brackish water (16), before the latter is passed to said body (12) of water.

12. An apparatus for the desalination of salt-containing water (16), comprising an evaporator (10) in which a body (12) of liquid can be located, with an air space (28) above the surface thereof, guide means (22) defining a web path (24) through said body (12) of liquid and said air space (28), drive means (34) for driving a web (26) of absorbent material along said web path (24), a condensation chamber (42) in gas connection with said air space (28) in said evaporator (10) and means (48) for providing a flow of air through said air space (28) over the surface of said web (26) and to said condensation chamber (42).

13. An apparatus according to claim 12, wherein said evaporator (10) has an inlet (14) for brackish water (16), an outlet (18) for salt-enriched liquid (20), guide rollers (22) defining a meandering path (24) for said web (26) through said air space (28), a fan (48) for directing air across the surface of said web (26), and a pipe (40) connecting said air space (28) to said condensation chamber (42), and said condensation chamber (42) is in said form of a cooling tower (42) with said pipe (40) from said evaporator (10) entering towards said bottom thereof, above an outlet (44) for said desalinated water.

The Patent Office

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Application No:	GB 9722864.7	**Examiner:**	John Warren
Claims searched:	1-13	**Date of search:**	26 February 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): B1B (BGA, BGC, BGD, BKE)

Int Cl (Ed.6): B01D 1/22, 3/00, 3/34; C02F 1/04, 1/08

Other: ONLINE Databases: WPI and CLAIMS

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 1 040 313	FOSTER WHEELER - see belt 3	
A	GB 0 461 875	BARREAU - see driven belt 11	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		